The Mathematics Needed in High School Physics

... *by* ...

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A Synopsis of
a thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in the Department of Education, in the Graduate College of the State University of Iowa

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The Mathematics Needed in High School Physics*

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The Problem

A review of some of the recent literature pertaining to high school physics shows that there is need for attention to some of the difficulties encountered in this subject.

Judd (4), for example, found that the percentage of pupils who elect science courses has steadily decreased, and that high school administrators say that such subjects are not as effectively taught as are the literary subjects.

Glenn (2) showed that physics teachers in over half of the fifty-nine Indiana high schools in his study regard their physics books too difficult for girls and one fourth regard them too difficult for boys. He found also that as many as 25% of the pupils who take this subject in some of the high schools fail to make a passing grade in it.

Randall, Chapman and Sutton (5) hold that pupils who have completed their high school physics course cannot solve ordinary physics problems satisfactorily.

Steele (7) found that 47% of the physics teachers in 155 Iowa high schools included in his study omitted half of the problems given by their textbook, and that approximately half of these teachers complained that their physics pupils used their algebra poorly. He found also that physics was required in 71% of the high schools included in his study.

In view of these findings, and others of a similar nature, this study was undertaken. Its chief purposes are:

1. To ascertain, by careful analysis, the mathematics needed to solve the problems in the five physics textbooks and laboratory manuals most frequently used in Iowa high schools in 1927-1928.
2. To construct an inventory test whose purposes are:
   (a) To be a means of testing the mathematical abilities needed to solve the problems in five high school physics textbooks and laboratory manuals.
   (b) To point out to mathematics teachers the items in their subjects which are useful in high school physics, and to serve as a guide in their remedial work.

* The author is indebted to School Science and Mathematics for permission to repeat any or all of his previous article which appeared in School Science and Mathematics in April, 1929. He is also indebted to Doctor Thomas J. Kirby of the University of Iowa for guidance throughout the study.

(c) To be a means of guidance. (To be given to the pupil before he makes a definite choice of high school physics as a subject for the following semester.)
(d) To be the basis for remedial work on the part of the physics teacher. (May be given early in first week of physics course, and may then be followed by a few days of intensive remedial work.)

Some Previous Studies

Studies by Glenn (2), by Randall, Chapman and Sutton (5), and by Steele (7) were referred to very briefly under the discussion of "The Problem." A few other significant studies will now be reviewed:

Burgess (1) constructed a battery of tests to secure objective measures of various abilities in high school physics. Part III involves "problems which in the collective experience of a group of teachers usually give difficulty to beginning students." He found the following factors, ranked in order of importance (most important first) to be contributory to physics ability:

(a) Interest in physics.
(b) Simple mathematics of physics.
(c) Observation aptitude.
(d) Reading comprehension.
(e) Number series and logic.

Gribble (3) attempted to find the relationship between success in physics, as ordinarily taught, and

(a) Reading ability.
(b) General intelligence.
(c) Certain mathematical abilities.

Although Gribble used only ninety pupils, he presents the following tentative conclusions:

(a) The correlation between reading ability and success in physics is low but positive.
(b) The correlation between general intelligence and success in physics is low but positive.
(c) The correlation between certain mathematical abilities and success in physics is higher than either of the foregoing correlations.

Reagan (6) made a careful analysis of Millikan and Gale's *A First Course in Physics* in order to ascertain the mathematical needs of high school pupils who use that text. He classified his results somewhat arbitrarily under the headings of arithmetic, algebra, and geometry, but failed to construct a test to be used.

Procedure

(A) Selection of the Textbooks Analyzed

In September 1928 a questionnaire was sent to a random sampling of 500 of the 946 public high schools in Iowa in

order to find out which five high school physics textbooks were most frequently used in that state. On the basis of replies received from 345 of these schools, the textbooks, in the order of frequency of use, were (most frequently used is given first):

1. Fuller, Brownlee and Baker.
2. Millikan and Gale (including Pyle's revision).
3. Carhart and Chute.
4. Black and Davis.
5. Dull.
6. A few scattered textbooks, such as Hoadley or Reed and Henderson, none of which was used in 2% of the schools.

(B) Technique in Analysis

The problems in the five most frequently used textbooks and laboratory manuals were first classified as mathematical-type and theory-type problems. By a mathematical-type problem is meant one whose solution involves quantitative treatment, whereas a theory-type problem is one whose solution does not require quantitative treatment. The former may be illustrated by: "Reduce 10 centimeters to inches," and the latter by: "Why can an athlete jump further in a running broad jump than in a standing broad jump?"

Table 1 shows the types of problems in the five physics textbooks analyzed:

TABLE 1

Types of Problems in the Five Leading Physics Textbooks

TEXTBOOKS	Theory Type		Math. Type		Total
	Number	%	Number	%	
Black and Davis	444	43.2	584	56.8	1028
Carhart and Chute	193	43.7	249	56.3	442
Dull	323	61.4	203	38.6	526
Fuller, Brownlee and Baker	1322	77.3	389	22.7	1711
Millikan and Gale (and Pyle)	375	58.4	267	41.6	642
Totals	2657	61.1	1692	38.9	4349
Average	531.4	56.8	338.4	43.2	869.8

All the mathematical-type problems in the three most frequently-used textbooks listed above were very carefully solved by every method that seemed reasonable to the author. Each problem was then recorded on the tabulation sheets. After having completed a careful analysis of the problems in the first three textbooks, the author solved the problems in Black and Davis and in Dull, but the processes involved were recorded on the tabulation sheets only in case the same process had not already been recorded for a problem in one of the

first three textbooks. In only a very small number of cases did the last two books involve a mathematical process not already recorded for one or more of the first three books analyzed.

Laboratory manuals were next examined, and the problems were solved, but the processes involved were not recorded on the tabulation sheets unless the same process was not already recorded for a problem in some textbook.

(C) Construction of the Test

After the analysis was completed, a tentative edition of an inventory test was constructed. In order to make the test of such length in its final form that it could be completed by the pupils in a laboratory period of eighty minutes or in two forty-minute periods, it was necessary to omit a very small number of items resulting from the analysis. It was therefore decided arbitrarily to omit any item which occurred in only one book and its manual unless it occurred at least ten times in that book and manual. It was also decided to omit any item which did not occur at least a total of three times in two or three books combined. It is held by the author that the omission of such items is not a serious handicap, since the great majority of the pupils will not come into contact with such items at all, and those pupils who do need those items may reasonably be expected to get help from their physics teacher when necessary, since there will be very few such occasions.

The tentative edition of the test has two forms, each of which requires approximately fifty minutes for completion. Part I of the tentative edition has seventy-one items, and these are usually classified, more or less arbitrarily, as arithmetic, algebra, and trigonometry. Part II of the tentative edition consists of twenty-one questions, and is concerned with items usually classified as plane geometry, although some of the items might well be otherwise classified.

Both parts of the tentative edition of the test were given to 265 pupils in nine high schools. None of these pupils had taken physics, but all of them could elect this subject at the beginning of the following semester or year.

On the basis of the results obtained by scoring the test papers of these 265 pupils, a revised edition of the test was constructed. A few of the items that occurred in the tenta-

tive edition of the test were not included in the revised edition for the following reasons:

(a) Some items were covered by other items in the test.
(b) Some items lacked objectivity.
(c) Since it was necessary to reduce the length of the test so that it could be completed in eighty minutes, a few items that appeared only a very small number of times were omitted.

A few alterations were made in the interest of clearness and objectivity. A few items were shifted from Part I to Part II in order to shorten Part I somewhat and lengthen Part II somewhat, so that each part can be taken in forty minutes.

In constructing the revised edition of the test, the first item in each part is the one that secured the greatest percentage of correct responses when given to the 265 pupils who took the tentative edition of the test. The last item in each part secured the smallest percentage of correct responses. The easiest items were placed first in order to encourage all pupils to continue with the test, and to prevent their "hanging up" on an item in the early part of the test.

Both parts of the revised edition of the test were given to 262 pupils in six high schools. None of these pupils had taken physics, but all were eligible to take it by the beginning of the following semester. None of these pupils had taken the tentative edition of the test.

Part I of the revised edition contains sixty-six items usually regarded as belonging to arithmetic and algebra. Part II contains twenty-four items usually regarded as belonging to plane geometry and trigonometry. Each part of the test can be taken in approximately forty minutes, and the entire test can be taken in a laboratory period of eighty minutes. A copy of the test, together with directions and tentative norms, may be obtained from the publisher, The Public School Publishing Company, Bloomington, Illinois.

Tables 2 and 3 show the percentage of correct responses made by the 262 pupils in six high schools included in the revised edition of the test. It will be noted that the items in the revised edition are not arranged exactly in the order of percentage of correct responses made by the 262 pupils. Among the reasons for a shifting in the position of some of these items are the following:

(a) Some items were altered somewhat in wording before being placed in the revised edition.

(b) The mere fact that an item is in a different position in the revised edition from what it was in the tentative edition, may have had some effect upon the percentage of correct responses.
(c) Problems in addition were written in horizontal form in one edition and in vertical form in the other edition.
(d) And perhaps most important among the reasons, there is a big difference in the preparation of pupils as well as of schools on various items.

TABLE 2

Percentage of Correct Responses
Part I, Revised Edition
(262 Pupils in Six Schools)

Items	Per Cent Correct	Items	Per Cent Correct	Items	Per Cent Correct
1	85.1	23	78.6	45	51.1
2	80.5	24	80.5	46	28.6
3	88.9	25	77.5	47	38.5
4	92.3	26	76.0	48	33.6
5	94.7	27	69.5	49	31.3
6	96.9	28	86.7	50	23.3
7	90.5	29	89.3	51	28.6
8	93.9	30	77.1	52	34.7
9	86.6	31	71.4	53	35.2
10	93.5	32	64.9	54	38.6
11	83.6	33	68.3	55	22.9
12	91.2	34	66.0	56	10.3
13	90.5	35	51.1	57	8.4
14	83.6	36	45.8	58	10.7
15	72.1	37	61.1	59	12.2
16	74.0	38	58.0	60	9.0
17	81.3	39	54.2	61	10.3
18	77.5	40	52.3	62	7.6
19	74.4	41	61.5	63	7.3
20	71.8	42	52.3	64	10.3
21	76.0	43	42.7	65	10.3
22	82.8	44	39.7	66	16.4
				Average	56.6

TABLE 3

Percentage of Correct Responses
Part II, Revised Edition
(262 Pupils in Six Schools)

Items	Per Cent Correct	Items	Per Cent Correct	Items	Per Cent Correct
1	97.7	9	82.1	17	37.4
2	93.9	10	57.2	18	72.1
3	90.9	11	84.0	19	50.0
4	82.8	12	61.8	20	43.1
5	79.8	13	89.3	21	64.5
6	74.8	14	56.0	22	49.2
7	77.9	15	58.0	23	49.2
8	85.1	16	50.8	24	21.0
				Average	67.4

Only four of the sixty-six items of Part I shifted their location over ten places, and the average number of places shifted in Part I is four places. Only five items in Part II shifted their location more than five places, and the average is three places. A shifting of as many of five or ten places will perhaps not affect the value of the test seriously. The pupils of some schools will always vary widely from the normal percentages of correct responses given to a certain item.

Statistical Considerations

Table 4 gives the frequency distribution of raw scores made by 262 pupils on Parts I and II of the revised edition combined. Table 5 gives the percentiles for Part I, for Part II, and for Parts I and II combined. It should be noted that adding the score for a given percentile for Parts I and II does not give the percentile recorded for Parts I and II combined. This is due to the fact that intervals of three were used for Part I, whereas intervals of one were used for Part II, and intervals of five were used for Parts I and II combined. The variation is in no case greater than two points, however.

In order to obtain the reliability of the test as a whole, a sampling of 200 papers covering the revised edition was used. The raw score of each of the 200 pupils was found on the odds, and then on the evens for each part of the test, and for the test as a whole. The scores on odd items were then correlated with the scores on even items of the test as a whole. This gave the correlation of half of the test versus half of the test. The Spearman-Brown formula was then applied, and the reliability of the test as a whole was found to be $.904 \pm .008$

The probable error of a raw score was found to be 1.4317. If this probable error were increased to 2.00, and if a pupil's raw score on the test as a whole were 70, the chances are 1 to 1 that the true score would lie between 68 and 72, and the chances are 1310 to 1 that the true score would lie between 60 and 80.

TABLE 4

Frequency Distribution of Raw Scores
Parts I and II Combined
Revised Edition

Interval	Number of Pupils Getting this Score
88-92	1
83-87	3
78-82	4
73-77	13
68-72	20
63-67	22
58-62	36
53-57	35
48-52	38
43-47	39
38-42	24
33-37	11
28-32	10
23-27	6
18-22	0
Total No. of Pupils	262
Mean Score	53.45
Median Score	52.93
Range of Scores	23-88
Highest Possible Score	90

TABLE 5

Percentiles for the Revised Edition
Part I, Part II, and Parts I and II Combined

Percentiles	Part I	Part II	Parts I and II Combined
90th	50.0	22.0	71.0
80th	46.0	21.0	65.0
75th	44.0	20.0	62.0
70th	43.0	19.0	60.0
60th	40.0	18.0	57.0
50th	37.0	17.0	53.0
40th	35.0	15.0	49.0
30th	31.0	14.0	46.0
25th	30.0	13.0	44.0
20th	30.0	12.0	43.0
10th	26.0	9.0	37.0

Conclusions

The following conclusions are indicated by this study:

1. The five physics textbooks most frequently used during 1927-1928 in the 345 high schools included in this study, are, in descending order of frequency of use: Fuller, Brownlee and Baker; Millikan and Gale (and Pyle); Carhart and Chute; Black and Davis; and Dull.
2. Physics was required in approximately 70% of the 345 Iowa high schools included in this study, and it is taught in grade twelve, only, in approximately 84% of these schools.
3. The mathematics needed in solving the problems of high school physics involves a considerable body of information usually taught in artithmetic, algebra and plane geometry. Not much trigonometry is needed.
4. Most of the mathematics needed to solve high school physics problems is not very difficult.
5. Most pupils who are eligible to take physics use their mathematics poorly. The median score on this test is only slightly above half of a perfect score on the test as a whole.
6. There is definite need for maintenance drills covering the mathematical items and processes needed in high school physics. A work-book providing adequate drill on these items and processes would be valuable.
7. In some cases the pupils respond very differently if items are written in vertical form instead of in horizontal form. Sometimes the advantage lies with the vertical form, and at other times with the horizontal form. In view of this fact, both forms should be included in the test.
8. There is considerable difference in the preparation of different pupils on certain items and processes. The difference in preparation of different schools is also significant.
9. Very few of the pupils who are eligible to take high school physics know how to find the reciprocal of a number or the sine of an angle. One of two courses might therefore be followed: (1) teachers of mathematics should teach these items well, and should give sufficient drill for maintenance, or (2) teachers of physics should

be advised that they themselves should teach these items. At any rate, a pre-test by the physics teacher is advisable.

10. The mathematics department should make sure that its pupils are well prepared on the items of this test before the pupils elect physics.
11. It seems advisable to give this test, or at least a similar test, at the beginning of the physics course. It will show whether the pupil is weak or strong in the mathematics needed in high school physics, and will indicate certain lines of attack.
12. It is probable that this test will have considerable value for prognosis, but proof of this assumption awaits further experimentation.
13. This test is not sufficiently reliable for a single pupil on a certain item, but it is fairly reliable for the class as a whole on a certain item. A comparable form of the test should be constructed. A more reliable measure would be secured by giving both forms of the test.
14. The percentiles set up may be used as tentative norms. A greater number of cases is necessary in order to make the norms more trustworthy.
15. It would be worth while to study the types of errors made by the pupils. This awaits further study.

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Editor's Note—A fuller discussion of this study is found in the author's doctor's thesis, which is on file in the library of the College of Education of the State University of Iowa, at Iowa City. Those who care to examine or use the test may obtain it from The Public School Publishing Company, Bloomington, Illinois.

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DIRECTIONS

for

An Inventory Test for the Mathematics Needed in High School Physics

PARTS I AND II

by

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PURPOSE OF THE TEST

Recent investigations show that in some schools approximately one-fourth of the pupils who take physics fail to make a passing grade in the subject; that physics pupils use their mathematics poorly; that teachers omit a large percentage of the problems given by the textbook; and that mathematical ability is one of the best criteria for predicting success in high school physics. In view of these facts, an attempt has been made to construct an Inventory Test for the Mathematics Needed in High School Physics. The purposes of this test are:

First: To point out to mathematics teachers those items in their subjects which are useful in high school physics, and to provide a means for testing the pupils on these items.

Second: To assist the administration in guiding pupils in their choice of high school physics. (Other factors such as interest, observation aptitude, and reading comprehension no doubt enter also into a prognostic testing for physics.)

Third: To provide an inventory test which may be given by the physics teacher during the first week of the course. (Although this test is not diagnostic in the strictest sense, it is valuable in pointing out many of the weak points and in indicating lines of attack for remedial work.)

CONSTRUCTION OF THE TEST

A questionnaire was sent to a random sampling of 500 Iowa high schools in the fall of 1927 in order to ascertain the names of the high school physics textbooks most frequently used. Replies were received from 345 of these 500 high schools. The five textbooks that were used in at least 2 percent of these 345 schools are, in alphabetical order:

Black and Davis
Carhart and Chute
Dull
Fuller, Brownlee and Baker
Millikan, Gale, and Pyle

All problems given in these five textbooks, together with their laboratory manuals, were then carefully solved by every correct method that one would expect the pupils to use. The processes involved were carefully recorded, and, on the basis of the data thus obtained, a tentative edition of the inventory test was built. In order to make it possible to complete the entire test in a laboratory period of 80 minutes, it was necessary to omit certain items that occurred only a few times, but the test provides almost a complete picture of what is needed. The tentative edition of the test was given to 265 pupils in nine high schools, and the papers were carefully scored. On the basis of results obtained by these pupils, the test was revised, so that the item which secured the greatest percentage of correct responses in each part of the test comes first, and the item which secured the lowest percentage of correct responses in each of the two parts comes last. A few items were omitted or were somewhat altered on the basis of responses in the tentative edition.

RELIABILITY

The revised edition of the test was given to 262 pupils in six high schools. On the basis of data thus obtained, the reliability of the test as a whole was found to be .904 $\pm$ .008, and the probable error of a raw score was found to be 1.4317. The total possible score is 90 for Parts I and II combined.

TENTATIVE NORMS

Percentiles	Parts of the Test		
	I	II	I and II
90	50	22	71
75	44	20	62
50	**37**	**17**	**54**
25	30	13	44
10	26	9	35

DIRECTIONS FOR GIVING THE TEST

Part I: Ask the pupils to fill in the blanks at the top of page 1, Part I. Be sure that they are provided with pencil or pen and scratch paper. Tell the pupils that they may use the scratch paper if necessary but that only the answers are to be recorded on the blanks at the right. Tell them also that they will have 40 minutes in which to complete the four pages of this part of the test and that they are to complete the test without further directions. At the end of 40 minutes, collect all papers.

Part II: Ask the pupils to fill in the blanks at the top of page 1, Part II. Be sure that each pupil will have access to a ruler, a compass, and a protractor. Tell the pupils that they may use scratch paper if necessary but that only the answers are to be recorded on the blanks at the right. Tell them that they will have 40 minutes in which to complete the four pages of this part of the test, and that they are to complete the test without further directions. At the end of 40 minutes, collect all papers.

DIRECTIONS FOR SCORING THE TEST

The answer key for Parts I and II is printed on a separate sheet. The answers are so spaced that they match the test exercises. By folding the answer sheet and placing the answers alongside the pupils' test papers, the tests may be scored rapidly and accurately. It is easier to score the same page of all test booklets before proceeding to the next page; i.e., first score page 1 of all test booklets, then page 2, etc.

Each exercise counts one point. Therefore, the highest possible score on Part I is 66 and the highest possible score on Part II is 24.

CLASS RECORD SHEET

School..... Teacher..... Grade.....

Date..... City..... State.....

DISTRIBUTION OF SCORES			
Part I		Part II	
Scores	No. of Pupils	Scores	No. of Pupils
65-66		24	
63-64		23	
61-62		22	
59-60		21	
57-58		20	
55-56		19	
53-54		18	
51-52		17	
49-50		16	
47-48		15	
45-46		14	
43-44		13	
41-42		12	
39-40		11	
37-38		10	
35-36		9	
33-34		8	
31-32		7	
29-30		6	
27-28		5	
25-26		4	
23-24		3	
21-22		2	
19-20		1	
17-18		0	
15-16		Total	
13-14		Median	
11-12			
9-10			
7-8			
5-6			
3-4			
1-2			
0			
Total			
Median			

Instructions for Recording Class Scores:

I. After the tests are scored, arrange the Part I tests in the order of the pupil's scores, from the highest to the lowest—keeping results from different classes separate.

II. Then count the number of pupils having a score of either 65 or 66, and enter the number of them opposite "65-66" under "No. of Pupils" in the column to the left. Then count the number of pupils having scores of 63 and 64, and enter them opposite "63-64." Proceed similarly to enter the number of pupils' papers having each of the indicated scores.

III. Add the numbers just entered and enter the sum after the word "Total."

IV. The Median is the score of the middle paper—if the number of papers is odd. If it is even, the median is the average score of the middle two papers. For example, if there are 35 papers, the median score is that of the 18th paper. If there are 36 papers, the median score is the average of the scores of the 18th and 19th papers. The computed median may also be found by the statistical method. (See Rugg, H. O., *Statistical Method Applied to Education*, pages 110-114.)

V. Proceed in the same manner to distribute the scores on Part II by arranging the test papers for Part II with the best paper on top. Enter first the number of pupils whose score is 24, then the number whose score is 23, etc. Total these entries and enter the number opposite the word "Total." Find the median in the same way as for Part I.

Tentative Medians

Part I	37
Part II	17

Kilzer-Kirby Inventory Test
for Mathematics of
High School Physics
PART I

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INVENTORY TEST
FOR THE MATHEMATICS OF HIGH SCHOOL PHYSICS

by L. R. Kilzer and T. J. Kirby

Name..... Grade..... Date.....

School..... City..... State.....

PART I

Directions for the pupil: Write the answer on the blank line at the right of each item. You may use scratch paper if necessary, but record only your answer. You will have 40 minutes in which to work the 4 pages of this test. When you have finished page 1, go right ahead with pages 2, 3, and 4. Try to do the entire test.

	ANSWERS
1. Multiply: 12y by 3	
2. Subtract: 3x from 5x	
3. Add: 3a and 4a	
4. Which of the following means that C is to be multiplied by itself? 2C, C_2, or C^2	
5. Reduce this fraction to lowest terms: $\frac{12}{15}$	
6. Find the value of y: $4y = 12$	
7. Divide 12a by 6	
8. Find the sum of: 16.40 23.08 41.22 34.34	
9. Divide: ab by a	
10. Multiply: $5(x + 2y - 5z)$	
11. Add: 3c and $-8c$	
12. Divide 18x by x	
13. Find the value of: 40^2	
14. How many lbs. does the ordinary ton contain?	

15. If D equals 10, h equals 15, and H equals 45, what is the value of d in this equation: $\frac{D}{d} = \frac{h}{H}$ .....

16. Find x: $\frac{x}{4} = \frac{9}{2}$ .....

17. Rd = ED: If R equals 100, d equals 2, and E equals 4, find value of D.....

18. John weighs 2 times as much as Mary. Harry weighs 40 pounds more than Mary. The combined weight of the three is 440 pounds. If X equals Mary's weight in pounds, what algebraic expression represents John's weight?.....

19. In problem 18, what algebraic expression represents Harry's weight?.....

20. Divide — 27d by — 9.....

21. The altitude of a rectangle is 2 ft., and the base is 6 ft. Find the area in sq. ft.....

22. Square: $\frac{3}{8}$ .....

23. Multiply — b by — b.....

24. In the accompanying graph, how many inches will a force of 10 pounds stretch a spring?

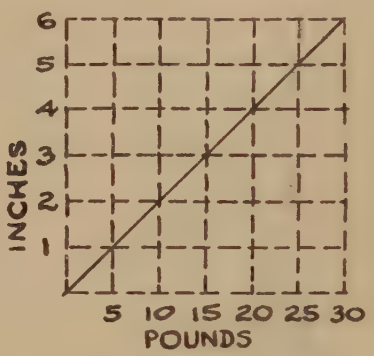

Fig. 1

Answer (question 24): _____

25. Find the square root of: $\frac{16}{25}$ .....

26. How many sq. in. does 1 sq. ft. contain?.....

27. How many ft. does 1 mile contain?.....

28. Find the value of 1^8.....

29. How many ounces are there in 1 lb. Avoir.?.....

30. Find the square root of: $49\,a^2\,b^4$.....

31. Factor: $x^2 - 3x - 10$ _____

32. Fill in the blanks: To find the average of 4 numbers, find their _____, and then _____ by _____.

33. Change .75 to per cent _____

34. Find value of $\frac{3}{4} \times \frac{8}{9} \times \frac{10}{15} =$
Give answer in lowest terms _____

35. The altitude of a rectangle is 2 ft., and the base is 6 ft. Give the formula that is used in finding the area _____ A = _____

36. John weighs 2 times as much as Mary, and Harry weighs 40 pounds more than Mary. Their combined weight is 440 pounds. If we let X equal Mary's weight, give the equation from which the weight of each can be found (combine the x's, but do not transpose) _____

37. Multiply: $(x - y)(x - y)$ _____

38. Refer back to the graph in problem 24. If the spring is stretched 4½ inches, what is the force in pounds? _____

39. Find a: $\frac{4}{a^2} = \frac{1}{16}$ _____

40. Expand: $(m - n)^2$ _____

41. Robert has $100. His money is to John's as 4 is to 5. How much has John? _____

42. If 5% of a number is 10, find the number _____

43. Change .045 to per cent _____

44. The radius of a circle is 2 inches. What is the formula for finding the area? _____ A = _____

45. Square 12.0512 (show 4 decimal places in answer) _____

46. Change $\frac{1}{9}$ to decimal form. Show three decimal places _____

47. How many cu. in. are there in 1 cu. ft.? _____

48. The radius of a circle is 2 inches. The area is _____ sq. in.

49. $s = \frac{1}{2} at^2$. If s equals 10 and a equals 5, find the value of t. _____

50. Simplify: $\frac{4}{\frac{7}{2}} =$ _____ _____

51. If $v = at$, find a _____ _____

52. 6 is what per cent of 30? _____ _____

53. The diameter of a circle is 10 inches. Find the circumference _____ _____

54. What is the formula used in problem 53? _____ C= _____

55. $\frac{F-32}{180} = \frac{3}{100}$ Find F _____ _____

56. Find t^2 if $\frac{1}{2}at^2 = 2s$ (avoid fractional denominator) _____ _____

57. $\frac{A}{B} = \sqrt{\frac{X}{Y}}$ If A equals 3, B equals 1, and Y equals 4, find X _____ _____

58. How many inches in 1 meter? _____ _____

59. How many cu. in. in 1 gal.? _____ _____

60. 1 kg. equals how many g.? _____ _____

61. 1 km. equals how many m.? _____ _____

62. $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ If p equals 18, and f equals 1.8, find the value of q _____ _____

63. How many cm. are there in 1 in.? _____ _____

64. How many cu. cm. (cc.) are there in 1 liter? _____ _____

65. Find the square root of 356.048. The answer should contain at least three decimal places _____ _____

66. Find the reciprocal of 5 _____ _____

Kilzer-Kirby Inventory Test
for Mathematics of
High School Physics
PART II

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INVENTORY TEST
FOR THE MATHEMATICS OF HIGH SCHOOL PHYSICS

by L. R. Kilzer and T. J. Kirby

Name..... Grade..... Date.....

School..... City..... State.....

PART II

Directions for the pupil: Write the answer on the blank line at the right of each item. You should have access to a ruler, compass, and protractor. You may use scratch paper, but record only your answer. You will have 40 minutes in which to work the 4 pages of the test. When you have finished page 1, go ahead with the rest of the test.

ANSWERS

1. In order to construct an angle of 45 degrees, we may bisect an angle of how many degrees?..... _____

2. In a certain triangle, A is the vertex angle, and B and C are the base angles. B and C each contains exactly 70 degrees. What two sides are equal?..... _____ & _____

3. What kind of triangle is ABC in problem 2?..... _____

4. In a certain figure, there are 6 angles about a point on one side of a straight line. What is their sum in degrees? _____

5. The sum of the interior angles of a triangle equals how many right angles?..... _____

6. Given line AB and point P outside line AB. By use of a compass, a perpendicular was dropped from P to AB. Write the letters abc so that they will show the order in which the steps they represent were drawn. (NOTE: If 2 parts of a construction are marked with the same letter it means that those two steps are interchangeable, and that letter should occur only ONCE in your answer.) Place the letters here:..... _____

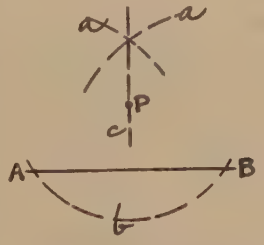


Fig. 2

7. An equiangular triangle is both isosceles and..... _____

8. Given line AB with point P on line AB. By use of a compass, a perpendicular was erected to AB at P. Write the letters abc so that they will show the order in which the processes they represent were drawn. See note in question 6.

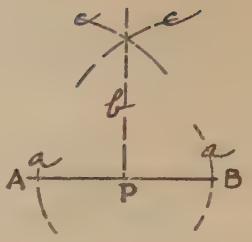


Fig. 3

Write letters here: _____

9. Below are 2 proposed methods for the construction of an angle of 60 degrees. Place a cross (X) after each correct method:
   (a) Construct an equilateral triangle. Each angle is then an angle of 60 degrees..... _____
   (b) Construct an isosceles right triangle. Each of the angles opposite the two equal sides is then an angle of 60 degrees..... _____

10. An exercise says: "Draw a parallelogram, given one side, a diagonal, and the angle between the given diagonal and the given side." In the figure at the right, let AB be the given side. What two angles could each comply with the given conditions?..... _____ & _____

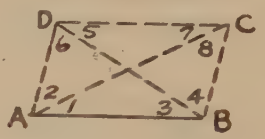


Fig. 4

11. Read the following axioms carefully:
   (a) If equals are added to equals the sums are equal.
   (b) If equals are subtracted from equals, the remainders are equal.
   (c) If equals are multiplied by equals, the products are equal.
   (d) If equals are divided by equals, the quotients are equal.
   (e) Things equal to the same thing or to equal things are equal to each other.
   (f) Like powers of equals are equal.
   (g) Like roots of equals are equal.

   At the right of the following equation, place the letter which designates the axiom which was used to get the second statement: $2x = 4$
   $x = 2$..... _____

12. Which of the axioms in question 11 was used to get the second statement here: $x - 5 = 10$
   $x - 5 + 5 = 10 + 5$..... _____

13. If 2 lines are perpendicular to each other, how many degrees are there in each angle thus formed?..... _____

14. At the right is a rough drawing of a protractor. Below it is line XY. Suppose that you were asked to use the protractor in constructing a perpendicular to XY at Y.

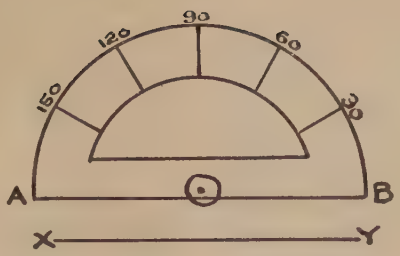


Fig. 5

Write the proper response on the blank lines at the right:

(a) Point O should be placed on point..... _____

(b) A dot should then be placed where the protractor reads how many degrees?..... _____

(c) Call this point E. With what point should E then be connected?..... _____

15. With a ruler divided into sixteenths of an inch, find the length of the line AB. (Fractions should be in the lowest terms.) The answer is..... _____ in.

Fig. 6

16. If ½ inch represents 10 pounds, how much force does line AB in exercise 15 represent?..... _____ lbs.

17. Given the 2 lines AB and CD intersecting at point O. By the use of the protractor, find the number of degrees in angles 1 and 3.

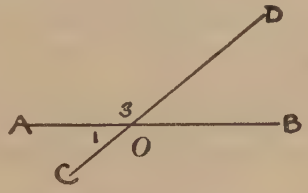


Fig. 7

(a) The number of degrees in angle 1 is..... _____°

(b) The number of degrees in angle 3 is..... _____

18. Refer again to the drawing of the protractor in problem 14 above. Suppose that you were asked to use the protractor to draw an angle of 30 degrees at point P on line XY.

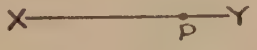


Fig. 8

(a) The protractor should be placed so that its base line AB will fall along..... _____

(b) Point O should fall upon point..... _____

(c) A dot should be placed where the protractor now reads either..... _____ or _____ degrees

(d) Call this point C. Then C should be connected with point..... _____

19. If the hypotenuse of a right triangle is 10 ft., and one leg is 8 ft., how long is the other leg?..... _____ ft.

20. Given the line AB and point p outside the line. Through point p the line XY has been drawn parallel to AB by the use of a compass and ruler. Write the small letters abcde so that they will show the order in which the steps they represent were drawn. (See note in question 6.)

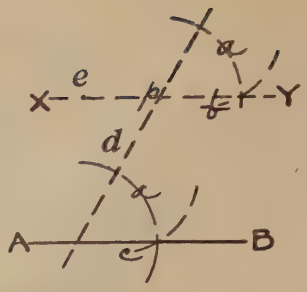


Fig. 9

Write the letters here: _____

21. Which of the axioms given in question 11 is applied in these equations? $x^2 = 25$ / $x = 5$ ..... _____

22. The figure ABC represents two sides and the included angle of a parallelogram. Place a cross (X) after each of the three processes, which when combined, will complete the parallelogram:

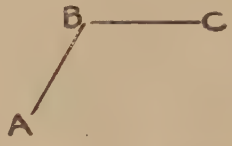


Fig. 10

(a) With A as a center and BC as a radius draw an arc _____

(b) With B as a center and AB as a radius draw an arc _____

(c) With C as a center and AB as a radius draw an arc _____

(d) Draw line AC ..... _____

(e) Connect intersection of arcs with A and C ..... _____

(f) Draw the altitude of the parallelogram ..... _____

23. Given the angle ABC. By use of ruler and compass, angle XYZ was constructed equal to angle ABC. Write the letters abcde so that they will show the order in which the steps they represent were drawn.

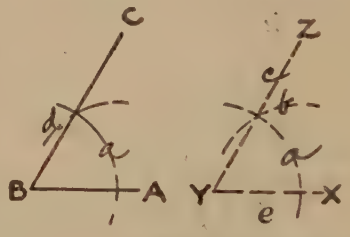
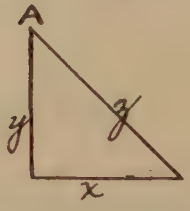


Fig. 11

The letters are: _____

24. In this right triangle, what is the sine of angle A?



Answer: _____

Answers, Kilzer-Kirby Mathematics-Physics Test, PART I

Page 1		Page 2		Page 3		Page 4	
	No.	Ans.	No.	Ans.	No.	Ans.	No.
		30	(15)	(x—5) (x+2)	(31)	2	(49)
		18	(16)			1 1/7 (or 1.142)	(50)
				sum, divide, four	(32)		
	(1)	50	(17)			v/t (or v ÷ t)	(51)
	(2)						
	(3)			75%	(33)	20%	(52)
	(4)	2x	(18)	4/9	(34)	31.416 (or 31 3/7 or 31.42)	(53)
						C = pi D (or π D)	(54)
	(5)	x + 40	(19)	A = bh (or ba)	(35)		
	(6)	3d	(20)			37.4	(55)
	(7)					4s/a	(56)
		12	(21)				
		9/64	(22)				
04	(8)			4x + 40 = 440	(36)	36	(57)
		b²	(23)				
	(9)			$x^2 - 2xy + y^2$	(37)	39.37 (or 39 +)	(58)
+ 10y — 25z	(10)					231	(59)
	(11)			22½ (or 22.5)	(38)		
	(12)					1000	(60)
	(13)			8	(39)	1000	(61)
	(14)			$m^2 - 2mn + n^2$	(40)		
						2	(62)
				125	(41)	2.54 (or 2½)	(63)
		2	(24)	200	(42)	1000	(64)
		4/5 (or .8)	(25)	4.5% (or 4½%)	(43)		
		144	(26)	A = pi r^2 (or π r^2)	(44)	18.869	(65)
		5280	(27)			1/5 (or .2)	(66)
		1	(28)	145.2314	(45)		
		16	(29)	.111	(46)		
		$7ab^2$	(30)	1728	(47)		
				12.5664 (or 12 4/7 or 12.57)	(48)		

Each correct answer counts one point.
The answer keys are so spaced that they will fit the test exercises. Fold on the lines and place the key alongside the students' test papers when scoring them. It is easier to score the same page of all test booklets before proceeding to the next page; that is, first score page one of all test booklets, then page two, etc.
Answers for Part II are on the other side of this sheet.

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Answers for Part II

Page 1		Page 2		Page 3		Page 4	
Ans.	No.	Ans.	No.	Ans.	No.	Ans.	No.
		acb	(8)			dacbe	(20)
				(a) Y			
				(b) 90		g	(21)
		(a) X	(9)	(c) Y	(14)		
				1¼	(15)		
						(a) X	
90	(1)	1 and 3 (or show 1 as CAB or BAC, & 3 as DBA or ABD)	(10)	25	(16)		
						(e) X	
AB and AC	(2)						
isosceles	(3)					(e) X	(22)
180	(4)			(a) 38, 39 or 40			
				(b) 140, 141 or 142	(17)		
2	(5)						
				(a) XY		eadbe	(23)
				(b) P			
		d	(11)				
				(c) 30 or 150			
bac	(6)	a	(12)	(d) P	(18)		
equilateral	(7)					x/z (or x ÷ z)	(24)
		90	(13)	6	(19)		

See other side for instructions and for answers for Part I.

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JUN 29 '33
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NOV 27 '34